

The Ordovician trilobite *Neseuretus* from Saudi Arabia, and the palaeogeography of the *Neseuretus* fauna related to Gondwanaland in the earlier Ordovician

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Synopsis

Neseuretus tristani (Desmarest) is figured from the Hanadir Shale, Saudi Arabia, only the second Ordovician trilobite described from the Arabian Peninsula. *Neseuretus* was an inshore genus, often accompanied by a sparse fauna of inarticulate brachiopods and bivalves, and confined to the cold-water, and presumably circumpolar shelf seas of the earlier Ordovician. It is regarded as the most sensitive indicator of the former extent of inshore facies in cooler seas fringing Gondwanaland in the earlier (Arenig–Llanvirn) Ordovician. A review of other occurrences of *Neseuretus* supports a united Gondwanaland as deduced from geophysical and whole-fauna evidence, but would also include the southern part of Europe and the southern part of China within the same continental block.

Introduction

As part of the Saudi Arabian Cover Rock Project, staff at the Royal School of Mines (Imperial College) have been mapping the Lower Palaeozoic rocks that outcrop along the edge of the Precambrian shield in the mid-part of the Arabian Peninsula. Several highly fossiliferous blocks were recovered from hard bands in the Hanadir Shale (Fig. 1), a unit at the base of the Tabuk Formation (Powers *et al.* 1966 : 112; McClure 1978), and overlying the widespread Saq Sandstone Formation of presumed Cambrian to Arenig age. The blocks proved to be crowded with the fragmentary remains of a species of the trilobite *Neseuretus*, accompanied by a few inarticulate brachiopods, bivalves, graptolites, nautiloids and conodonts. The trilobites are well preserved, and since the only other Ordovician trilobite from the Arabian peninsula is a *Plaesiacomia* species described by Thomas (1977), are well worth illustrating. Moreover, *Neseuretus* is a genus of particular palaeobiogeographic significance, and this opportunity is taken to assess its distribution in relation to the Gondwanaland of the earlier Ordovician. We are particularly grateful to Dr J. Ferguson and Dr R. G. Davies for donating this material to us for study. We also thank Dr N. J. Morris and Dr L. R. M. Cocks for determinations.

Palaeogeography of the *Neseuretus* fauna

Definition of the early Ordovician Gondwanaland

Faunas with *Neseuretus* are associated with inshore, epicratonic deposits at what were high latitudes in the earlier part of the Ordovician. Often, as in Saudi Arabia, *Neseuretus* is the only trilobite. Numerous *Neseuretus* may be accompanied by one or two other trilobites such as *Ogyginus*, *Crozonaspis* or *Merlinia*, but apart from a few species of inarticulate brachiopods and bivalves other associated fauna is sparse. Such a low-diversity fauna is



Fig. 1 Photograph of fossiliferous locality at Aṭ-Ṭinīyāt, Jabal Shammar, north Saudi Arabia. The arrow indicates the *Neseuretus* horizon. (Photo by Dr J. Ferguson).

exactly what might be expected of an inshore environment at high latitude; the living crab *Hyas coarctatus* is the only well-skeletized decapod species which is at all common at Arctic latitudes today. We regard the *Neseuretus* fauna, and by extension *Neseuretus* itself, as the best indicator of epicontinental seas at relatively high latitudes. Dean (1976) and Cocks & Fortey (1982) used this criterion to infer geographic continuity of the Anglo-Welsh area with southern Europe and north Africa in the earlier Ordovician. We here attempt to extend worldwide the analysis of Dean (1976), to see how the description of this fauna relates to alternative reconstructions of Gondwanaland.

This is a somewhat different approach to deducing continental configuration from that of Whittington & Hughes (1972). These authors compared whole faunas at generic level, and excluded faunas of small diversity ('less than ten taxa'; 1972 : 238). But an important feature of the *Neseuretus* fauna in many occurrences is precisely its low diversity. Here we plot the distribution of a particular facies fauna, the one which, being the most inshore, we deduce would have been most responsive to constraints such as geography and ambient temperature. Deep water faunas include more widespread genera and have more interprovincial 'mixing', albeit with a concomitantly higher diversity. So we contend that the distribution of *Neseuretus* is, *prima facie*, an indication of the extent of relatively high-latitude areas in the Ordovician, and likely also to indicate close geographic proximity. It is important to emphasize that the distribution considerations only apply to the earlier half of the Ordovician, i.e. Arenig to Llandeilo, because many different lines of evidence lead to the conclusion that by the Caradoc palaeogeography and continental distribution were changing fundamentally. We also exclude the distribution of the related genus *Vietnamia* Kobayashi, 1960, but include the subgenus *Neseuretus* (*Neseuretinus*) Dean, 1967, partly because it is difficult to decide to which subgenus poorly preserved species belong.

The distribution of the trilobite *Neseuretus* is paralleled by the distribution of particular suites of sedimentary facies which extend into areas where the characteristic trilobite has not yet been found (Dean 1976). *Neseuretus*-bearing beds are often underlain by and sometimes interbedded with coarse to fine quartzites of Grès Armoricaïn type. As Bergström (1976) has noted, presumed trilobite trace fossils of the genera *Rusophycus* and *Cruziana* (especially *C. furcifera*) often accompany the *Neseuretus* body fossils. *Neseuretus*-bearing beds are often enriched in iron compounds, as in eastern Newfoundland, parts of southern Europe and in Saudi Arabia. Free calcium carbonate appears to be invariably absent.

Neseuretus has been described from Arenig rocks of the Avalon platform, eastern Newfoundland (Dean & Martin 1978), where it is associated with *Ogyginus* and numerous *Cruziana* trails, and with rich sedimentary ironstones. Arenig occurrences are typical of the transgressive beds at the base of the series in south Wales (Fortey & Owens 1978), and throughout the relatively inshore facies of the Mytton Flags, Shropshire. In the Gorran Quartzites of Cornwall (Sadler 1974) its occurrence is Llandeilian, and Llanvirn-Llandeilo occurrences are typical of a great number of localities in Brittany (Henry 1970) and the Iberian Peninsula (Hammann 1976; Sadler 1974: text-fig. 2), where, however, it is absent from the extreme inshore facies of the underlying Arenig. Destombes (1971) records *Neseuretus* from both Arenig and Llanvirn Formations in Morocco. Dean (1966) has described two *Neseuretus* species from the Montagne Noire, southern France, of Arenig age. Moving eastwards, *Neseuretus* is known from the Arenig of the Taurus Mountains, Turkey (Dean 1971). In Algeria the facies is closely similar to that of Europe (Legrand 1974), inshore and ferruginous with trace fossils and a sparse bivalve and inarticulate brachiopod fauna including *Lingulobolus brimonti*, a species of wide distribution in the Armorican Quartzite facies (see Havlíček, 1980). Whiteman (1971) records *Neseuretus* from a number of Algerian localities, and indicates the continuation of the same suite of rocks into Tunisia. The same facies also continues eastwards into Libya, but we cannot find any faunal records.

The Saudi Arabian occurrence reported here forms a link between the European and African occurrences and those further to the east. There is no published record of *Neseuretus* from Iran and Iraq, although reports of *Cruziana*-rich arenaceous facies (Čtyroky 1973, Dietrich 1937) indicate that the right type of shallow water facies was present in both countries. We accept Dean's (1967) redetermination of *Calymene birmanica* Reed, 1906, from the Shan States, Burma, as a *Neseuretus* species and examination of the types of *Calymene nivalis* Salter (1865b : 10) from the Himalayas suggests that this species also may be referred here. In China eight or more species of *Neseuretus* have been reported (from west to east) from the western Yunnan (Sheng 1974), southern Szechwan and southern Shensi (Lu 1975), all from the Llanvirn. The Ordovician faunas in general along this region are of 'European' aspect, and strikingly different from those of north China (e.g. Wang 1980),

which are of North American Midcontinent type, and presumably lay near the Ordovician equator, separated by the Tsin Ling suture of Ziegler *et al.* (1977).

In South America *Neseuretus* is recorded from the Llanvirnian of Bolivia (Přibyl & Vaněk 1980), northern Argentina (Harrington & Leanza 1957) and the 'Arenig or Llanvirn' of Peru (Dean 1976 : 243). The 'European' flavour of Ordovician faunas of the northern part of South America has been appreciated for a long time (e.g. Kobayashi 1937), and has recently been emphasized again (Hughes *et al.* 1980) in the case of an offshore fauna from Peru. Whittington & Hughes (1974) emphasize faunal continuity between South America and the rest of Gondwanaland during the Tremadoc. The *Neseuretus* fauna is of limited geographical extent, reflecting the restricted distribution of the appropriate facies in the right climatic zone.

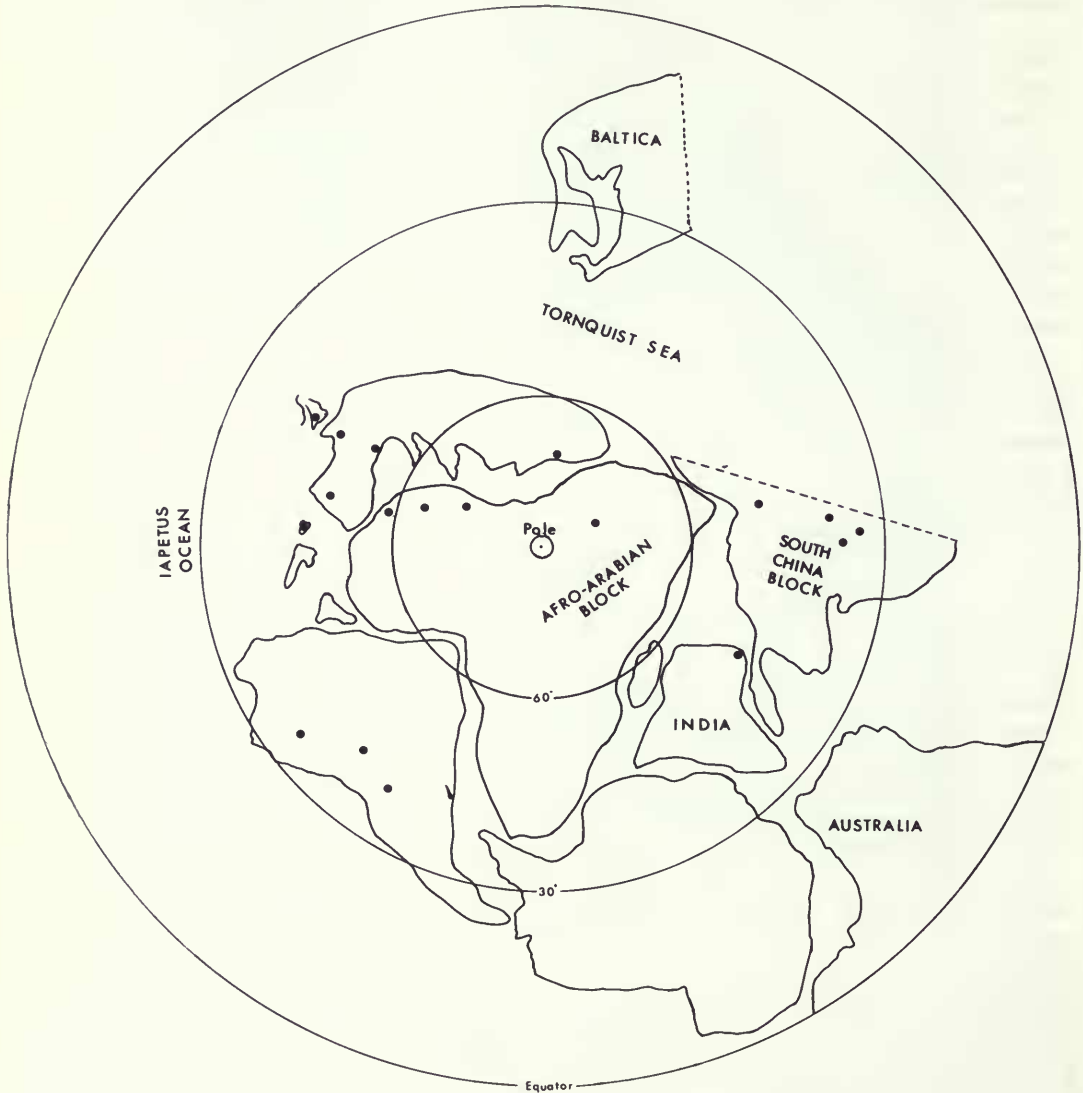


Fig. 2 Palaeogeographic reconstruction of the southern hemisphere (excluding North America) for the Lower Ordovician. The occurrence of *Neseuretus* is indicated. (After Whittington & Hughes 1972).

Gondwanaland in the earlier Ordovician

If the controls on the distribution of *Neseuretus* are as we have suggested it should be a sensitive indicator of the inshore, cold seas of Gondwanaland. This would imply (Fig. 2) a broadly united Gondwanan continent in the earlier Ordovician, including southern Europe attached to north Africa, and including also the southern part of China. This picture is in general agreement with previous Ordovician reconstructions, with Gondwanaland in a polar position (Whittington & Hughes 1972, 1974; Embleton & Valencio 1977; Scotese *et al.* 1979; Bambach, Scotese & Zeigler 1980; Burrett & Richardson 1980). If one makes the assumption that the *Neseuretus* faunas are approximately symmetrically distributed about the pole, this would give a pole position in the region of the eastern part of Africa; the Saudi Arabian occurrence would be closest to the pole. There are, however, several differences between the reconstruction Gondwanaland and adjacent continents based on the distribution of the *Neseuretus* fauna and those cited above.

Scotese *et al.* (1979) and Bambach, Scotese & Zeigler (1980) show the Baltic continent ('Baltica') at very high latitudes in the Middle Ordovician, close to Gondwanaland. This is highly improbable, because the *Neseuretus* fauna is absent from Baltica, and if it was close and at the same latitude there would be no reason to prevent establishment of the fauna. Cocks & Fortey (1982) have advanced reasons why Baltica should be at temperate latitudes and separated from southern Europe by a substantial ocean ('Tornquist's').

Whittington & Hughes (1972: fig. 3) show southern Europe separated from north Africa by a 'Proto-Tethys' ocean. In accordance with Dean (1976), we believe that the distribution of the *Neseuretus* fauna and facies—which extends even to identity at specific level in the Llanvirn—argues against any such oceanic tract. Note that the distribution of the *Neseuretus* fauna is equivalent to the *Selenopeltis* fauna of Whittington & Hughes plus part of the *Asaphopsis* fauna, plus several of those classified as of 'uncertain affinity'. Whittington & Hughes' (1974) Tremadoc faunas are geographically much more widespread, which we would attribute to the transgressive (and hence relatively deep-water and more cosmopolitan) sedimentary regimes on a world-wide scale during this period.

The distribution given here would have to include south-east Asia (including the southern part of China) in Gondwanaland, which differs from the reconstructions of Zeigler and his co-workers, who would have this area as a separate plate at low latitudes. That interpretation would entail the *Neseuretus* fauna not only living under different conditions but also crossing the palaeoequator. A continuity of trilobite faunas in the Cambrian, similar to that accepted by us for the earlier Ordovician, has been argued by Chang (1980).

Position of Australia

There is considerable evidence to indicate that Australia lay within equatorial latitudes in the Tremadoc and Arenig. Graptolite, cephalopod and conodont faunas are typical of equatorial faunas elsewhere, and the platform limestones of western Queensland and other areas of the continental interior are of usual low latitude type. Arenig-Llanvirn platformal trilobite faunas have never been completely described, but are under study by J. Shergold and R. A. Fortey. Pelagic elements are the same as in other circumequatorial faunas, but the benthic faunas include a number of curious endemic genera, including a bizarre local radiation of Asaphidae. There are also a few 'Gondwanan' elements (but not *Neseuretus*) such as *Hungiooides* which are known from South America, southern China, or both. It seems reasonable to accept the attachment of Australia to Gondwanaland as in the Whittington & Hughes (1974) and Scotese *et al.* (1977) maps, and accord it an equatorial position. The southern part of Argentina also presumably extended towards lower latitudes. Here should be mentioned the record of ?*Neseuretus* by Legg (1976) from the Arenig of the Canning Basin, northwestern Australia. Unfortunately these are pygidia only, of calymenacean type, and it seems more probable to us that another genus is represented; certainly the associated fauna is generally unlike that of the *Neseuretus* fauna, and the geographical position would be most anomalous.

Associated fauna

Age. Dr J. Ferguson informs us that the fossil bed with trilobites which we have examined is both overlain and underlain by graptolitic shales. It consists entirely of 'tuning fork' graptolites, among which *Didymograptus purchisoni*, *D. cf. geminus*, *D. artus* and *D. cf. spinulosus* were identified. This is without doubt an assemblage of Llanvirn age, and very likely within the upper Llanvirn Zone of *D. purchisoni*. The age of the trilobite fauna is therefore also late Llanvirnian. Broken didymograptid stipes occur within the trilobite bed itself.

Dr L. R. M. Cocks has determined three genera of inarticulate brachiopods, which occur in the same blocks as the trilobites: *Schizocrania?*, *Monobolina* and *Lingulella*. Of these, *Monobolina* is significant in being a restricted Anglo-Welsh to southern European genus, typically found in shallow water facies. The bivalves include *Glyptarca cf. naranjoana* (Verneuil & Barrande, 1855) (Dr N. J. Morris det.); this was originally described from Spain.

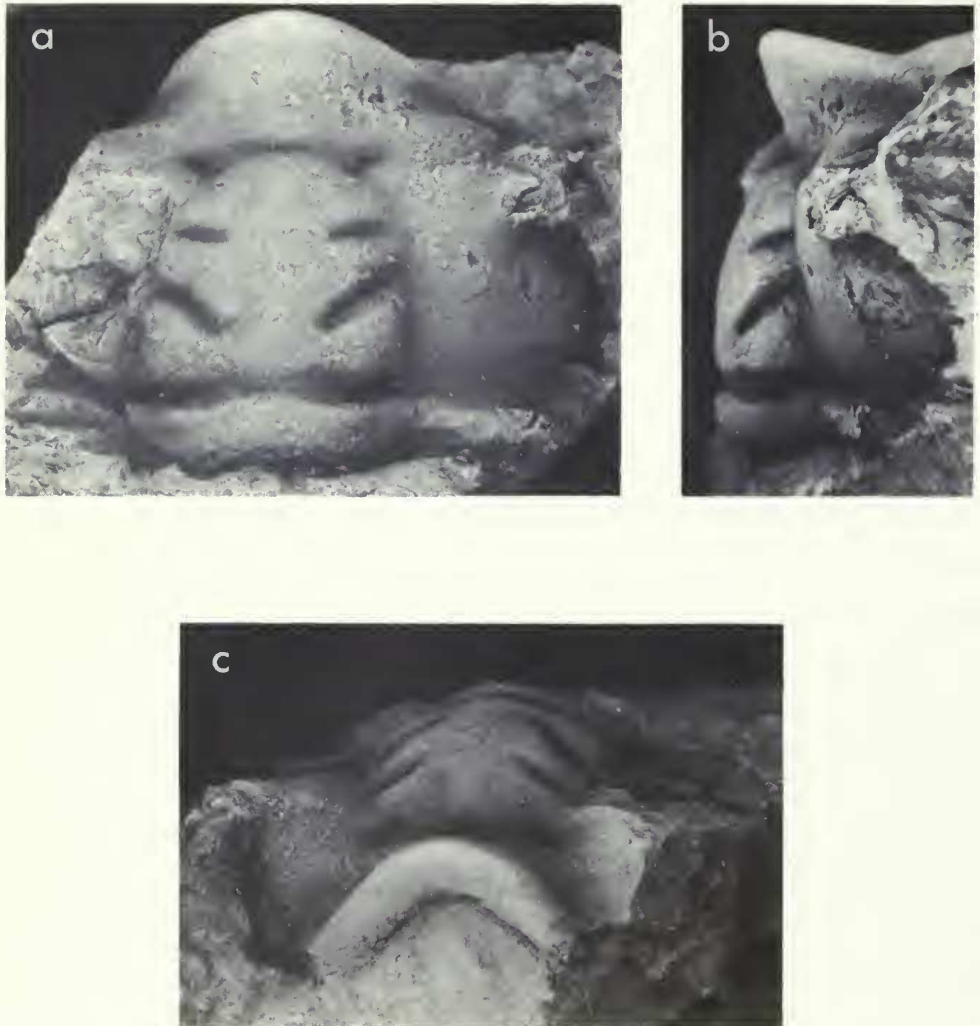


Fig. 3 *Neseuretus tristani* (Desmarest, 1817). Cranidium It.15738. Llanvirn Series, Hanadir Shale; Aṭ-Ṭīnīyāt, Saudi Arabia. a, dorsal view, $\times 3$. b, right lateral view, $\times 2.5$. c, anterior view, $\times 3$.

Both the bivalve and the brachiopods are associated with the trilobite *Neseuretus* at their other localities. Together they constitute a characteristic assemblage of fossils—an inshore, low diversity fauna from clastic facies—which may be termed the *Neseuretus* fauna (*Neseuretus* community type of Fortey & Owens, 1978). Thomas (1977) described a species of the trilobite *Plaesiacomia* from a different locality in the Hanadir Shale. *Plaesiacomia* is another trilobite of restricted, boreal distribution in the earlier Ordovician (Dean 1976), but is generally found in deeper water facies than *Neseuretus*.

Lithology. Mrs J. Bevan has kindly examined the rock yielding the body fossils under the electron probe. The trilobites themselves have been replaced by an iron-rich dolomite. The rock includes mudflakes (composed of fine orthoclase, quartz and dolomite), and significant quantities of iron oxide (probably limonite) grains, set in a matrix of fine dolomite, feldspar and quartz. The trilobites are entirely preserved as disarticulated parts, often densely stacked on one another. The rock is evidently a coquina.

Systematic note

Family CALYMENIDAE Burmeister, 1843

Neseuretus has been assigned to a separate family Synhomalonotidae Kobayashi, 1960. We accept here the arguments advanced by Henry (1980) that the hypostoma in particular indicates calymenid affinities.

Genus *NESEURETUS* Hicks, 1873

TYPE SPECIES. *Calymene parvifrons* var. *murchisoni* Salter, 1865; see Whittard 1960 : 139.

DATE OF AUTHORSHIP. The date of authorship of *Neseuretus* has been variously quoted as 1872 (Whittard 1960, Dean 1966, Dean & Martin 1978), 1873 (Henry 1980) or 1876 (Dean 1967). Hicks' paper appears in the first part of volume 29 of the *Quarterly Journal of the Geological Society of London*. Each page carries the date 'Nov. 1872', which is presumably the source of the 1872 date of publication. However, the cover page (which also includes on the reverse an account of Society business transacted early in 1873) bears the date 1873, which is the correct year of publication. November 1872 is the date of the meeting at which Hicks' paper was presented.

SPECIES INCLUDED in *Neseuretus* (*Neseuretus*).

<i>N. antetristani</i> Dean, 1966	Arenig; France
<i>N. arenosus</i> Dean, 1966	Arenig; France
<i>N. attenuatus</i> (Gigout, 1951)	? Llanvirn; Morocco
<i>N. avus</i> Hammann, 1977	early Llanvirn; Spain
<i>N. bergeroni</i> (Thoral, 1935)	Arenig; France
<i>N. brevisulcus</i> Whittard, 1960	Lower Arenig; England
<i>N. bullatus</i> Whittard, 1960	Lower Llanvirn; England
<i>N. complanatus</i> Whittard, 1960	Lower Arenig; England
<i>N. concavus</i> Lu, 1975	Llanvirn; Shensi, China
<i>N. concavus tenellus</i> Lu, 1975	Upper Llanvirn; Shensi, China
<i>N. convexus</i> (Sheng, 1958)	Upper Llanvirn; Szechuan, China
<i>N. ?elongatus</i> Hicks, 1873	Arenig; Wales
<i>N. equalis</i> Lu, in Lu & Chang 1974	Lower Ordovician; Szechuan, China
<i>N. expansus</i> Lu, 1975	Llanvirn; Shensi, China
<i>N. grandior</i> Whittard, 1960	early Arenig; England, West Germany
<i>N. henkei</i> Hammann, 1977	Llandeilo; Spain
<i>N. intermedius</i> Lu, 1975	Llanvirn; Szechuan, China
<i>N. kayseri</i> (Kobayashi, 1951)	Arenig/Llanvirn; Szechuan, China
<i>N. kobayashi</i> (Harrington & Leanza, 1957)	Llanvirn; Argentina, Bolivia

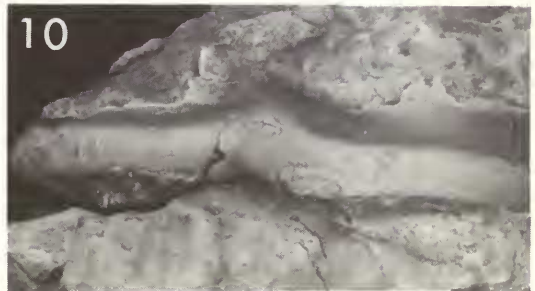
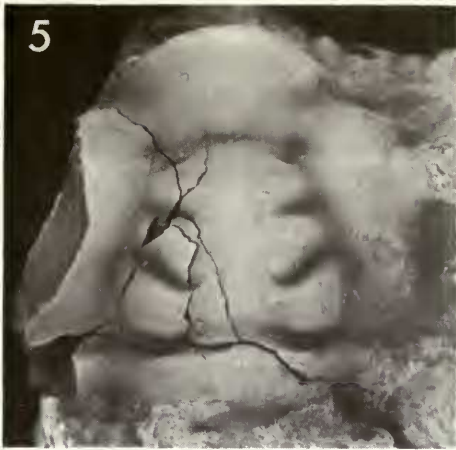
<i>N. lusitanicus</i> (Thadeu, 1949)	Llandeilo; Portugal
<i>N. monensis</i> (Shirley, 1936)	Arenig; Wales
<i>N. munchisoni</i> Salter, 1865a	Arenig; Wales, England
<i>N. nivalis</i> (Salter, 1865b)	mid-Ordovician; central Himalayas
<i>N. pamiricus</i> Balashova, 1966	Llandeilo; Pamirs
<i>N. parvifrons</i> (M'Coy, 1851)	Arenig; Wales
<i>N. planus</i> Lu, 1975	Llanvirn; Shensi and Szechuan, China
<i>N. ? quadratus</i> Hicks, 1873	Arenig; Wales
<i>N. ramseyensis</i> Hicks, 1873	Arenig; Wales
<i>N. sanhwaichangensis</i> Lu, 1975	Llanvirn; Szechuan, China
<i>N. sanlucaensis</i> Přibyl & Vaněk, 1980	Llanvirn; Bolivia
<i>N. sexangulus</i> Dean, 1971	Lower Arenig; France
<i>N. shensiensis</i> (Lu, 1957)	Llanvirn; Shensi, China
<i>N. tristani</i> (Desmarest, 1817)	Upper Llanvirn–Llandeilo; France, Portugal, Spain, England, Algeria
<i>N. tristani</i> or <i>parvifrons</i> (of Whiteman, 1971)	Llanvirn or Llandeilo; Tunisia
<i>N. tungtzuensis</i> (Sheng, 1958)	Upper Llanvirn; Yunnan, China
<i>N. vaningeni</i> Dean, in Dean & Martin 1978	Lower Arenig; Newfoundland
<i>N. yinganensis</i> [? Chang, in Chang <i>et al.</i> 1979]; apparently a <i>nomen nudum</i>	Caradoc; Xinjiang, China
<i>N. zunyiensis</i> Yin, 1978	Arenig; Kweichou, China
<i>N. ? sp.</i> (Dean, 1971)	Arenig; Turkey
<i>N. sp.</i> (Destombes, 1967)	early Arenig; Morocco
<i>N. sp.</i> (Destombes, 1967)	Llandeilo; Morocco
<i>N. sp.</i> (Henry, 1980)	Llandeilo; north-west France
<i>N. sp.</i> (Whiteman, 1971)	Arenig; Algeria
<i>N. sp. nov.</i> (Whiteman, 1971)	Arenig; Algeria
<i>N. spp. nov.</i> (Whiteman, 1971)	Llanvirn; Algeria
<i>N. sp.</i> (Dean, 1975)	Arenig or Llanvirn; Peru
<i>N. ? sp.</i> (Kobayashi, 1951)	Llanvirn; Kweichou, China



Fig. 4 *Neseuretus tristani* (Desmarest, 1817). Cranidium It.15740, dorsal view, $\times 3$. Llanvirn Series, Hanadir Shale; Aṭ-Ṭīnīyāt, Saudi Arabia.

Neseuretus tristani (Desmarest, 1817)
Figs 3–11

Although usually attributed to Brongniart (1822) there is a valid proposition of the species in Desmarest (1817 : 517). Desmarest uses the name with reference to a Brongniart work in preparation, but this does not have formal status. For subsequent synonymy see Henry (1970, 1980) and Sadler (1974).



Figs 5–10 *Neseuretus tristani* (Desmarest, 1817). Llanvirn Series, Hanadir Shale; Aṭ-Ṭinīyāt, Saudi Arabia. Fig. 5, dorsal view of small cranium It.15739, $\times 3$. Fig. 6, dorsal view of pygidium It.15748, $\times 3$. Fig. 7, dorsal view of fixed cheek It.15741, $\times 2.5$. Fig. 8, free cheek It.15742, $\times 3$. Fig. 9, posterior view of pygidium It.15744, $\times 2.5$. Fig. 10, portion of thoracic segment It.15743, $\times 3$.

MATERIAL. More than fifty fragments of this species were recovered, of which the following are registered in the collections: crania: It.15738–41; free cheek: It.15742; thoracic segment: It.15743; pygidia: It.15744–48.

LOCALITY AND HORIZON. Aṭ-Ṭīnīyāt, Jabal Shammar, northern Saudi Arabia; 27° 41' N, 42° 20' E. Llanvirn Series, Tabuk Formation, Hanadir Shale, Zone of *Didymograptus murchisoni*.

REMARKS. This species has been extensively revised by Henry (1970, 1980) and Sadler (1974) and further description is unnecessary. It is possible to match every feature given in Henry's recent, careful and well-illustrated account in the Saudi Arabian material. The lateral cranial profile is identical, with the long frontal border relatively steeply upturned, compared with the British species of Arenig age (Henry 1970 : fig. 2). The only species of Llanvirn age from Britain, *N. bullatus* Whittard, 1960, has a short frontal area, like *N. vaningeni* Dean, in Dean & Martin 1978, from the Arenig of eastern Newfoundland. The vaulting on the cranial border is particularly marked in *N. tristani*. We have obtained specimens (see Fig. 4) which show the muscle insertion areas and fine granulation clearly on the external surface; these compare closely with the specimen in Henry (1980 : pl. 10, fig. 3). Some of the other specimens from Saudi Arabia (Fig. 3) appear to be almost without granulation; we regard this as an intraspecific variation only. Other species of *Neseuretus* do not appear to have defined 1P muscle insertion areas, which are prominent on some specimens of *N. tristani*. The deflexion of the 1P glabellar furrow around the back of this muscle insertion area presumably accounts for the sigmoidal form of 1P in many Homalonotidae and Calymenidae. We note one small difference on pygidia of our material compared with the descriptions of Henry (1970, 1980); Henry describes as many as nine axial rings in total, of which the first six or seven pass across the mid-part of the axis. No more than six axial rings are defined across the mid-part of the axis on Arabian specimens, with up to two more faint impressions on the terminal piece. In other respects, such as sculpture and relative definition of pleural and interpleural furrows, the French specimens are so similar to ours that we cannot consider a specific distinction on the basis of this pygidial difference alone. The Arabian form is also close to the species identified as *N. birmanicus* (Reed) from Yunnan by Sheng (1974 : pl. 8, figs 2a–g) which differs mainly in having a weakly defined cranial rim or border. Dean (1967) assigned *N. birmanicus*, *sensu stricto*, to his subgenus



Fig. 11 *Neseuretus tristani* (Desmarest, 1817). Dorsal view of pygidium It.15744, $\times 2.5$. Llanvirn Series, Hanadir Shale; Aṭ-Ṭīnīyāt, Saudi Arabia.

Neseuretinus on the basis of a defined cranidial border. The material illustrated by Sheng includes (1974 : pl. 8, fig. 2d) specimens with a border no better defined than that of the type species of *Neseuretus*, *N. murchisoni* (compare Whittard, 1960 : pl. 20, fig. 14), and the Yunnan species should evidently be placed in *Neseuretus* in a restricted sense. We conclude that *N. tristani*, together with what may be very closely related species, extended over much of Gondwanaland in the Llanvirn.

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